Tutorial sheet 5
Second law analysis and Availability

1. A Hilch tube has an air inlet flow at 20°C, 200 kPa and two exit flows of 100 kPa, one at 0°C and the other at 40°C. The tube has no external heat transfer and no work and all the flows are SSSF and have negligible kinetic energy. Find the fraction of the inlet flow that comes out at 0°C. Is this setup possible? (9.11) Ans: 0.5, s_{gen}=.1966kJ/k so possible

2. Two flowstreams of water, one at 0.6 MPa, saturated vapor, and the other at 0.6 MPa, 600°C, mix adiabatically in a SSSF process to produce a single flow out at 0.6 MPa, 400°C. Find the total entropy generation for this process. (9.12) Ans: 0.128 Kj/kg-k

3. Carbon dioxide at 300 K, 200 kPa is brought through a SSSF device where it is heated to 500 K by a 600 K reservoir in a constant pressure process. Find the specific work, heat transfer and entropy generation. (9.17) Ans: 187.1 kJ/kg, 0.1626 kJ/kg-k

4. A supply of 5 kg/s ammonia at 500 kPa, 20°C is needed. Two sources are available one is saturated liquid at 20°C and the other is at 500 kPa, 140°C. Flows from the two sources are fed through valves to an insulated SSSFmixing chamber, which then produces the desired output state. Find the two source mass flow rates and the total rate of entropy generation by this setup. (9.23) Ans. 0.852 kW/K

5. Air from a line at 12 MPa, 15°C, flows into a 500-L rigid tank that initially contained air at ambient conditions, 100 kPa, 15°C. The process occurs rapidly and is essentially adiabatic. The valve is closed when the pressure inside reaches some value, P_2. The tank eventually cools to room temperature, at which time the pressure inside is 5 MPa. What is the pressure P_2? What is the net entropy change for the overall process? (9.27) Ans: 6.96Mpa, 15.265 kJ/k

6. A 1-m^3 rigid tank contains 100 kg R-22 at ambient temperature, 15°C. A valve on top of the tank is opened, and saturated vapor is throttled to ambient pressure, 100 kPa, and flows to a collector system. During the process the temperature inside the tank remains at 15°C. The valve is closed when no more liquid remains inside. Calculate the heat transfer to the tank and total entropy generation in the process. (9.30) Ans: q=13156 kJ, s_{gen}=12.38 kJ/K

7. An old abandoned saltmine, 100000 m^3 in volume, contains air at 290 K, 100 kPa. The mine is used for energy storage so the local power plant pumps it up to 2.1 MPa using outside air at 290 K, 100 kPa. Assume the pump is ideal and the process is adiabatic. Find the final mass and temperature of the air and the required pump work. Overnight, the air in the mine cools down to 400 K. Find the final pressure and heat transfer. (9.31) Ans: T2=680K, w12=-2.322×10^8 kJ, p3=1235kpa, q23 = -2.265×10^8kJ

8. A rigid steel bottle, V = 0.25 m^3, contains air at 100 kPa, 300 K. The bottle is

now charged with air from a line at 260 K, 6 MPa to a bottle pressure of 5 MPa, state 2, and the valve is closed. Assume that the process is adiabatic, and the charge always is uniform. In storage, the bottle slowly returns to room temperature at 300 K, state 3. Find the final mass, the temperature T_2, the final pressure P_3, the heat transfer $_1Q_3$ and the total entropy generation. (9.32) q=-539.2 kJ, s_{gen}= 4.423kJ/K

9. A rigid 1.0 m^3 tank contains water initially at 120°C, with 50 % liquid and 50% vapor, by volume. A pressure-relief valve on the top of the tank is set to 1.0 MPa (the tank pressure cannot exceed 1.0 MPa - water will be discharged instead). Heat is now transferred to the tank from a 200°C heat source until the tank contains saturated vapor at 1.0 MPa. Calculate the heat transfer to the tank and show that this process does not violate the second law. (9.35) q=1072080 kJ, s_gen=120.4 kJ/K

10. A large storage tank contains liquefied natural gas (LNG), which may be assumed to be pure methane. The tank contains saturated liquid at ambient pressure, 100 kPa; it is to be pumped to 500 kPa and fed to a pipeline at the rate of 0.5 kg/s. How much power input is required for the pump, assuming it to be reversible? (9.40) Ans: 0.473 KW